Excretory Product and their Elimination

Date

* Introduction

- Animal accumulate urea, ammonia, uric acid, ions, CO_2, water in blood mainly by two methods
  (i) excess ingestion → intake of food
  (ii) metabolic reaction

- The nitrogenous waste has to removed totally (100%) or partially (partical removal)

- Human store small amount of urea to maintain osmolarity.

- In this chapter, we will read about nitrogenous waste

- There are three major form of nitrogenous waste
  (1) Ammonia (2) Urea (3) Uric acid

* Ammonia

- Highly toxic
- require marium amount of H_2O for its removal

- Ammonia is excreted as ammonium ions by the process of diffusion through body surface and gills.

- process of removal of ammonia is known as ammonotelism.

- Animal excreting ammonia is known as ammonotelic
  e.g. bony fish, aquatic amphibia, aquatic insect

- Ammonia is highly souble in water

- There is no role of kidney in fishes

* Urea

- Urea is less toxic than ammonia and high toxic than uric acid.

- Urea require medium amount of water for its removal

- process ÷ ureotelism
- Animal ÷ ureotelic

ex: mammals, terrestrial amphibian

- Ammonia is converted in urea in liver (ornithine cycle)
- Urea is filtered from blood in kidney and urine is formed.

Note:- Urea is partially removed in human.

* Uric acid
- Least toxic
- Minimum amount of water is required for its removal.
- removed as "~~pase~~ "paste and pellet"
- process:- uricotelism

Animal :- uricotelic

ex:- reptiles, bird/pavo, insect, land snail

note:- Order of toxicity / H_2O requirment

Ammonia > urea > uric acid

* Animal and its excretory structure

Excretory structure	Animals
(1) Flame cell or, protonephridia	flatworm/platyhelminthes, rotifers, some annelids, Cephalochordate (amphioxus)
(2) Nephridia	some annelids, earthworm
(3) Malphigian tubule	Insects (cockroach)
(4) Caxal gland	spider
(5) green gland or, antennal gland	crustacean (prawn)
(6) Kidney	vertebrate

* Human excretory system

- Human excretory system consist of :- one pair kidney, one pair ureter, one urinary bladder, one urethra.

* Kidney
- Bean shaped
- length ÷ 10-12 cm
  width ÷ 5-7 cm
  thickness ÷ 2-3 cm
  weight ÷ 120-170 gm
  } for adult human

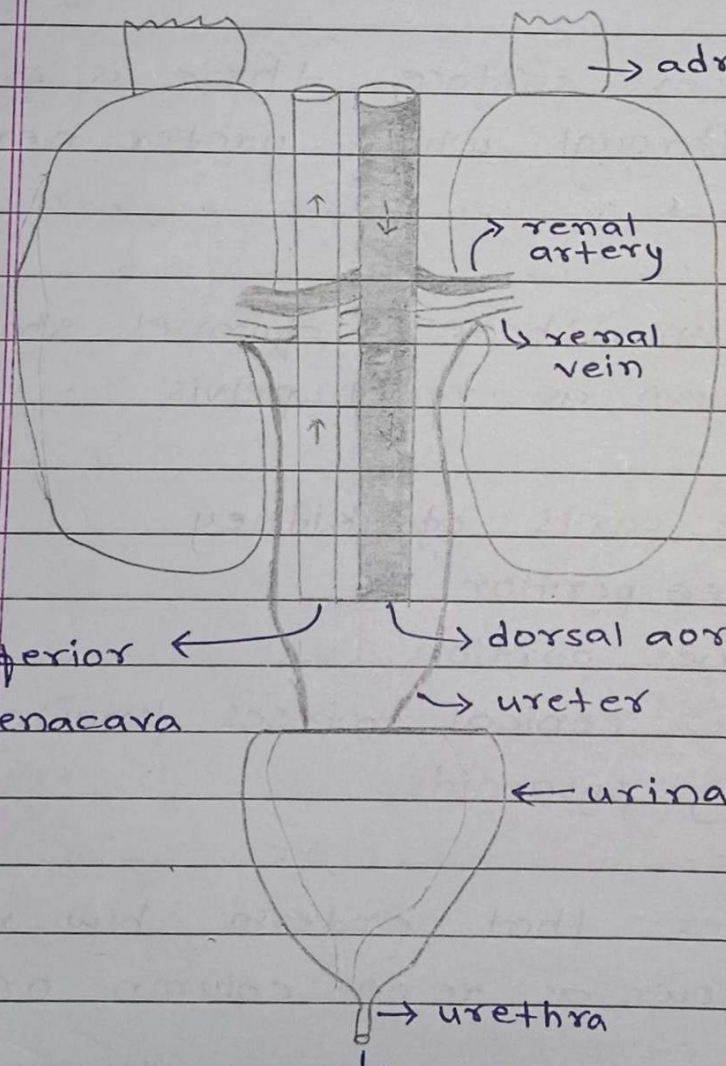
* Structure of kidney

- Covered by renal capsule (thick, fibrous)
- In inner concave surface, there is a noth called hilum through which ureter, nerves enters.
- Inner to hilum, there is funnel shaped structure known as renal pelvis.
- There are two parts of kidney
  (i) cortex ÷ outer portion
  (ii) medulla ÷ inner portion
    ↳ has few conical masses known as medullary pyramids
- portion of corter that extend b/w medullary pyramid is known as renal column or column of Bertini

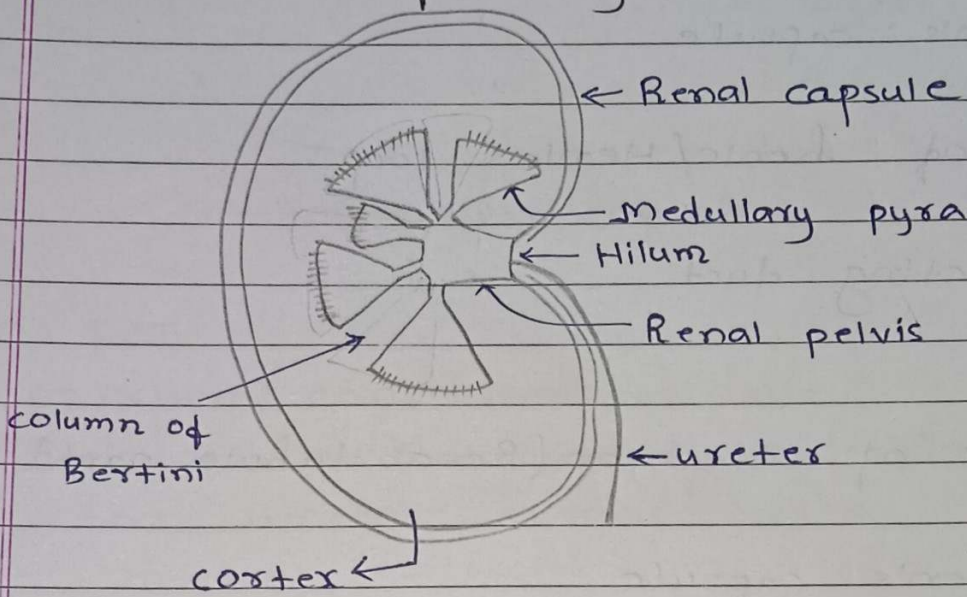
- Medullary pyramids projected into calyces

- location of kidney: b/w T_{12} and l_3 (dorsal) in abdominal cavity.
  Here, T= thoracic vertebrae and l = lumber vertebrae

* Structure of Human excretory system



* Structure of Kidney



* Nephron

- Structural and functional unit of kidney
- One kidney have one million nephrons
- Nephron has two parts
(1) Glomerulus (2) Renal tubule

(1) Glomerulus

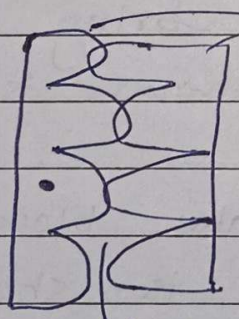
- Tuft of capillaries
- Afferent arteriole will bring blood into glomerulus, and it's diameter is large.
- Efferent arteriole will take blood away from glomerulus its diameter is short

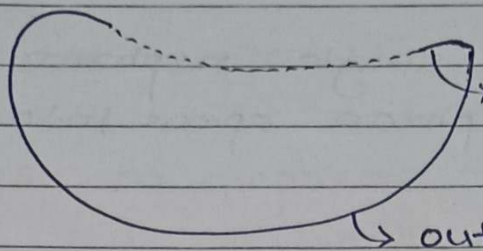
(2) Renal tubule
- Bowan's capsule
- PCT
- loop of henle/Henle's loop
- DCT
- collecting duct

* Parts of Nephron (Renal tubule part)

(1) Bowen's capsule
- Cup like structure
- double walled
(i) outer layer/parietal layer
(ii) inner layer/visceral layer
↳ has podocyte cell arranged in interi-cate manner forming filtration through which filtration is done.

- After filtration, filtrate enter in lumen of Bowaman's capsule





Bowman's capsule

(2) PCT
- proximal convoluted tubule
- It has brush-boarded cuboidal epithelium that increase surface area.

(3) Loop of henle / Henle's loop
- hairpin shaped
- 2 limbs

(i) descending limb (ii) ascending limb

- Ascending limb has two segments

(i) Thin segment (squamous epithelium)
(ii) Thick segment (cuboidal epithelium)

(4) DCT
- ~~Des~~ Distal convoluted tube
- It has cuboidal epithelium

(5) Collecting duct
- straight tube
- end portion of collecting duct is Duct of Bellini

- Not part of a single nephron, many DCT of many nephron opens into single collecting duct

- In cortax of kidney ÷ glomerulus, PCT, DCT and Bowman's capsule

- In medulla of kidney ÷ loop of Henle, collecting duct.

- Efferent arteriole forms network of capillaries around PCT, DCT which is known as peritubular capillaries.

- peritubular capillary that run close and parallel to loop of Henle, is called vasa recta.

- Vasa recta has two limbs
(i) Descending limb and (ii) Ascending limb

* Types of nephron

- There are two types of nephron

(i) Cortical nephron (ii) juxtamedullary nephrons.

(1) Cortical nephron

- Major part in corter of kidney
- 80-85% of nephron is cortical nephron
- Short loop of Henle
- vasa recta is reduced or absent

(2) Juxtamedullary nephron

- long loop of Henle is present
- 15-20% of nephron is juxtamedullary nephron
- loop of Henle runs deep into medulla.
- vasa recta is present

* Flow of blood in Kidney

Heart → Dorsal aorta → Renal artery → Afferent arteriole → Glomerulus → Efferent arteriole → peritubular capillaries → Vasa recta → Renal vein → Inferior venacava → Heart

* Flow of urine

Collecting duct → Duct of Bellini →

Minor calyx → Major calyx → Renal pelvis

→ Ureter → Urinary bladder → Urethra

→ Urethral meatus

* Urine formation

- There are three steps in urine formation, taking place in different part of nephron.

(i) Glomerular ultrafiltration
(ii) Tubular reabsorption
(iii) Tubular secretion.

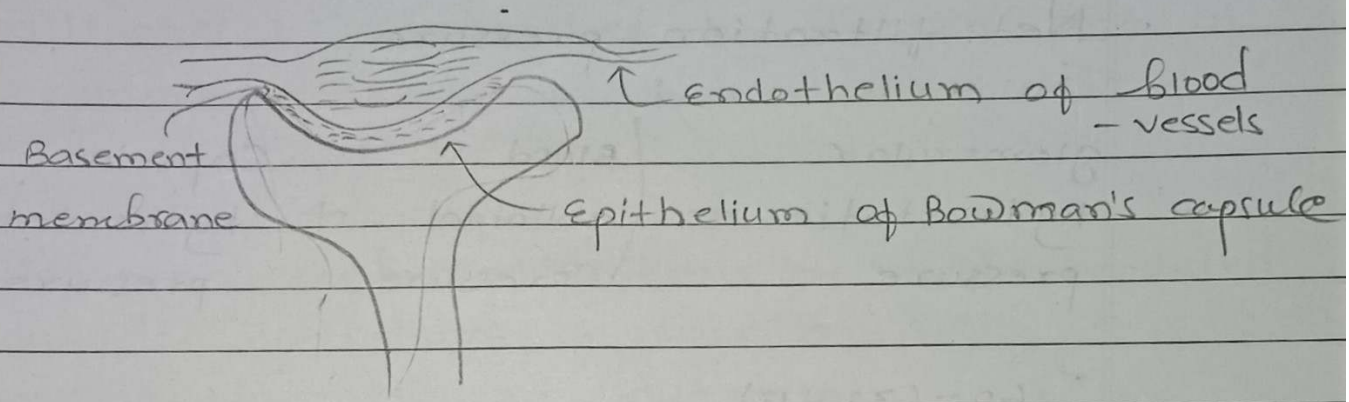
* Glomerular ultrafiltration

- Filtration done by glomerulus so finely, it is known as glomerular ultrafiltration.

- podocytes cells are present on visceral layer of Bowman's capsule forms filtration slits or slit pores through ——

Which filtration is done

- Filtration is done through three membrane:
  (i) Endothelium of blood vessels of glomerulus
  (ii) Epithelium of Bowman's capsule
  (iii) Basement membrane b/w them.



- There are three pressure during glomerulus filtration.

(1) Glomerular hydrostatic pressure
- promote filtration
- Diameter of afferent arteriole is more than diameter of efferent arteriole
- +60 mmHg

(2) Blood collodial osmatic pressure
- Resist filtration
- Due to colloid or protein molecule present in blood
- −32 mmHg

(3) Capsular hydrostatic pressure
- Resist filtration
- Due to filtrate present in lumen of Bowman's capsule
- -18mmHg

- Net filtration pressure

$$\text{glomerular hydrostatic pressure} - \left(\text{Blood colloidal pressure} + \text{Capsular hydrostatic pressure}\right)$$

$60 - (32 + 18)$
$= 10\text{mmHg}$

Note :-
- 20% or $\frac{1}{5}$th (1100 - 1200ml) of cardiac output is supplied to both kidney per minute
- Renal plasma flow = 650ml/minute
- ~~Glomerula~~
- Glomerular filtration rate (GFR) is amount of filtrate formed per minute.

* Tubular reabsorption
↳ in tubular part ↳ 2nd time absorption in body, 1st time absorption during digestion.

- 180L filtrate is formed in one day, but we excrete only 1–1.5L of urine. 99% of filtrate is reabsorbed by tubular part of nephron.

- In PCT
  - Maximum reabsorption (due to brush-bordered -cuboidal epithelium, surface area ↑)
  - 100% reabsorption of nutrients.
  - 70–80% reabsorption of H_2O, electrolytes
  - Active reabsorption of Na^+, amino acid, glucose
  - passive reabsorption of N_2 waste and H_2O
  - absorption of HCO_3^-

- Loop of Henle
  - two limbs are here

(1) Descending limb
- permeable to H_2O
- impermeable to electrolyte
- As filtrate moves down in descending limb, concentration of filtrate is done

(2) Ascending limb

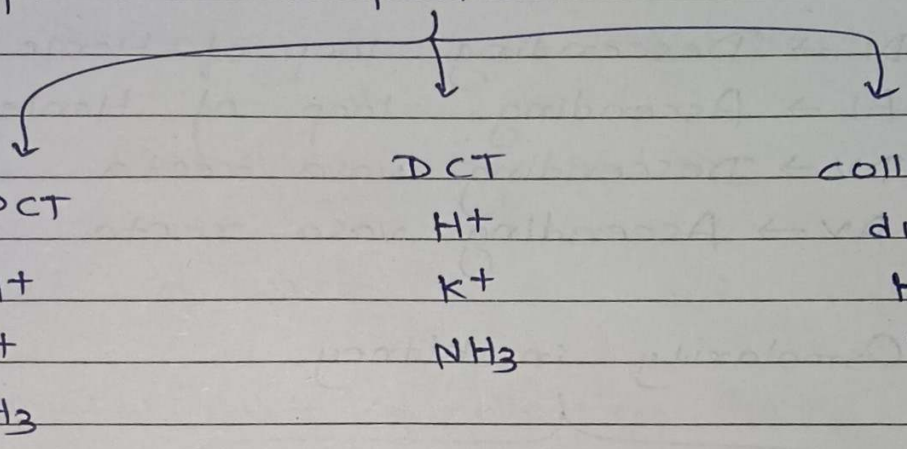
- permeable to electrolyte (active or passive)
- impermeable to H_2O
- As concentrated filtrate moves up in ascending limb of loop of Henle, dilution is done
  ↳ ↓ concentration

- In DCT
  - Conditional reabsorption of H_2O and Na^+ under influence of hormone.
  - reabsorption of HCO_3^-

- In collecting duct
  - H_2O can reabsorbed from collecting duct to produce concentrated urine.
  - Small amount of urea is also reabsorbed from distal part of collecting duct to maintain osmolarity hence, partial removal of urea is done in our body.

* Tubular secretion

- In filtrate, substance are added by the body in tubular parts of nephron
- Take place in 3 portion



Note: H^+ maintain acid- base (pH) balance in our body

K^+ maintain $Na^+ - K^+$ (ionic) balance in our body

* Counter - current mechanism

↳ opposite ↳ flow of fluid

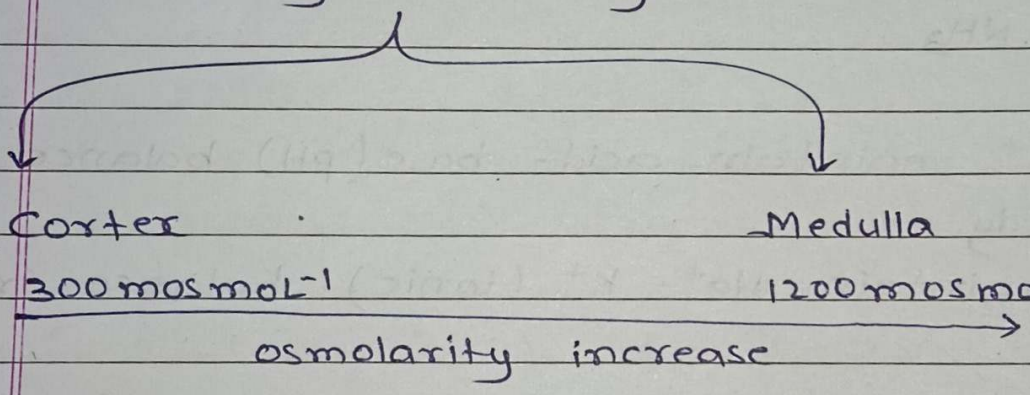
- Mammals have ability to produce concentrated urine
- Loop of Henle and vasa recta play important role in this.

mosmol^{-1}
(milli os mol per litre

- Counter - current flow b/w :-
  (i) DL and AL
  (ii) DV and AV
  (iii) DL and ~~AV~~ AV
  (iv) AL and DV

DL → Descending loop of Henle
AL → Ascending loop of Henle
DV → Descending vasa recta
AV → Ascending vasa recta

- Osmolarity in kidney



- Counter - current flow and proximity b/w loop of Henle and vasa recta helps to maintain osmolarity gradient in kidney.

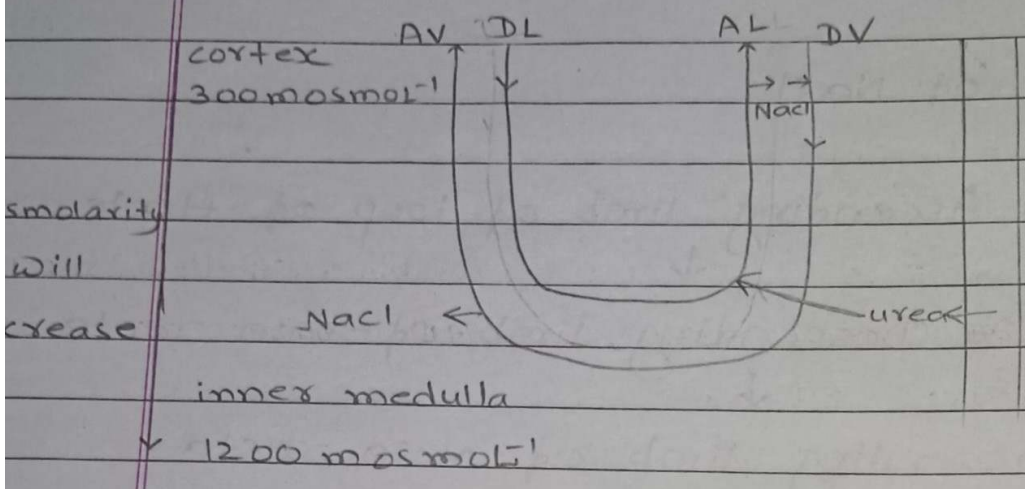
- Transport of NaCl

Ascending limb of loop of Henle
↓
Descending limb of vasa recta
↓
Ascending limb of vasa recta
↓
Medullary interstitum

- Transport of urea

Distal part of collecting duct
↓
Medullary interstitum
↓
Ascending limb of loop of Henle
↓
collecting duct

Note: NaCl and urea maintain high osmolarity of medullary interstitum



counter-current mechanism

* Regulation of kidney

Hypothalamus

JGA
& Juxto
glomerular
apparatus

Heart
↓
↓ GFR

↑ Blood pressure
↑ Blood volume
↑ GFR

* Hypothalamus

Blood volume ↓
Blood pressure ↓ ⟶ Osmorecepter get switched ON
Fluid volume ↓
Ionic concentration ↓

→ ~~Singte~~ Signal to hypothalamus → signal to posterior pituitary or Neurohypophysis → release vasopressin or ADH (anti-diuretic hormone)

↓ Vasoconstriction
· constriction of vessels

↓ Work on DCT and cause conditional reabsorption of H_2O

· When, blood pressure ↑
Body fluid volume ↑ ⟶ osmorecepter get OFF →

No signal to hypothalmus → ADH released is suppressed

* JGA

- Juxta Glomerular Appartus
- sensitive region in kidney, formed by :-

(i) Special cell of afferent arteriole → JG cell (juxta glomerular)

(ii) Special cell of DCT → Macula dense cell

- When blood pressure and blood volume decrease

↓

JG cell release renin

(renin) ↓ ACE (from lungs) ↓

Angiotensinogen → Angiotensin I → Angiotensin II

Angiotensin-II

Act as vasoconstrictor

act on cortex of adrenal gland

↓

Aldosterone

↓

cause reabsorption of Na^+ and H_2O from DCT of nephron

- Overall, blood pressure, GFR increases
- This mechanism is known as RAAS / RAM

RAAS → Renin Angiotensin Aldosterone System

RAM → Renin Angiotensin Mechanism

* Regulation of kidney by heart

When blood flow in atria ↑

↓

Atria of heart release ANF (atrial natriuretic factor)

↓

ANF acts as vasodilator (dilation of blood vessels)

↓

Blood pressure, GFR ↓

Note :- ANF keeps check on RAAS/RAM

* Micturition

- Release of urine is known as micturition
- Voluntary action
- Neural mechanism of micturition is known as micturition reflex

- During Micturition (urination)

→ Outer sphinter (voluntary in nature) relax.
→ Smooth muscle of urinary bladder contracts

- Mechanism

As urinary bladder fills with urine
↓
Wall of urinary bladder stretch, stretch receptor present on walls of urinary bladder get swithched on
↓
Stretch receptor initiate signal and send to CNS
↓
Motor signal generate in respone causing release of urine

* Characteristic of urine
- light yellow in color
- Slightly acid (pH = 6)
- Characteristic odour
- 1 - 1.5L of urine is excreted ~~in~~ out by adult human/day
- 25 - 30gm of urea is excreted out per day
- Urine is also used for clinical diagnosis purpose
- Glycosurea ÷ presence of glucose in urine
- Ketonurea ÷ " " Kenton in urine

→ symptoms of diabetes mellitus

* Rule of other excretory organs

(1) Lungs
- remove CO_2 and H_2O
- 200ml CO_2/minute

(2) Liver
- secrete substances like bilirubin, biliverdin, degrated steriod substances, hormone etc
- liver is the largest gland of our body

(3) Skin

- Have sebaceous and sweat gland
- Sweat gland secrete sweat containing Nacl, lactin acid, small amount of urea.
- primary function of sweat gland is to provide cooling effect to body.
- Sebaceous gland produce sebum, having sterol, hydrocarbon, wax. It provide ~~protection~~ protective covering to skin

* Disorders of excretory system

(1) Haemodialysis

→ Malfunctioning of kidney cause increase level of urea in blood, ~~thin~~ e this condition is known as haemodialysis

- In haemodialysis

Blood from convenient artery

↓

Add anti-cogulant (heparin) to it

↓

pass it through dialysing unit

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↓

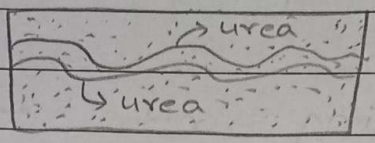
Filtered blood is introduces in body through vein after adding anti- heparin

* Dialysing unit

- In dialysing unit, coiled cellophane tube is present
- Outside cellophane tube, dialysing fluid is present
- Dialysing fluid has same composition as that of plasma (but it lacks urea)
- particle moves according to concentration gradient.
- Urea will move from high concentration (from blood) to low concentration (to dialysing fluid)
- In this way blood is filtrated.

* Haemodialysis

Uremic patient $\xrightarrow{\text{artery}}$ blood + heparin

→ dialysing unit 

→

filtrated blood + anti-heparin $\xrightarrow{\text{vein}}$ Uremic patient

- Renal calculi :- Accumulation of insouble masses or salt (oxalate) in kidney
- Glomerulonephritis :- Inflammation of glomeruli of kidney

note:- kidney transplantation is ultimate method for acute renal failure.